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ELECTRONIC DEVICE

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BACKGROUND OF THE INVENTION

The present invention relates to a technique for performing solder bonding through the use of a temperature hierarchy effective in the module mounting of electronic devices, etc.

In Sn-Pb-base solders, soldering has so far been performed by temperature-hierarchical bonding in which parts are soldered first at temperatures between 330°C and 350°C by use of high-temperature solders, such as Pb-rich Pb-5 mass % Sn (hereinafter the indication of "mass %" is omitted and only a numeral is recited) solders (melting point: 314-310°C) and Pb-10Sn solders (melting point: 302-275°C), and bonding is then performed with the aid of Sn-37Pb eutectics (183°C) of a low-temperature solder without melting soldered portions. This temperature-hierarchical bonding is adopted in semiconductor devices in which chips are die bonded, and in semiconductor devices of flip chip bonding, etc. In other words, in semiconductor fabrication processes, it has become important to provide temperature-hierarchical bonding between a solder used within a semiconductor device and another solder for bonding the semiconductor device itself to a substrate.

On the other hand, in some products there

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have been cases in which bonding at a temperature of not more than 290°C is required in consideration of the heat resistance limit of parts. As solders in a composition range for high-temperature soldering suited to this requirement in conventional Sn-Pb-base solders, a Pb-15Sn solder (liquidus temperature: 285°C) and solders with similar compositions can be conceived. However, when the Sn content becomes higher than this level, low-temperature eutectics (183°C) precipitate. Furthermore, when the Sn content becomes lower than this level, the liquidus temperature rises, with the result that bonding at a temperature of not more than 290°C becomes difficult. For this reason, even in a case where a secondary reflow solder for bonding to a printed circuit board is a eutectic Sn-Pb-base solder, it has become impossible to avoid the problem of remelting of bonds of high-temperature solder. When Pb-free solders are used for secondary reflow, bonding is performed at temperatures of 240-250°C, which are about 20-30°C higher than with eutectic Sn-Pb-base solders, and therefore the bonding at a temperature of not more than 290°C becomes more difficult.

More specifically, at present there is no high-temperature Pb-free soldering materials that permit temperature-hierarchical bonding at a soldering temperature ranging from 330 to 350°C or at a temperature level of 290°C.

This situation is described in detail below.

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At present, Pb-free solders are being used in increasingly many applications in terms of environmental issues. In Pb-free solders for soldering to printed circuit boards, eutectic Sn-Ag-base solders, 5 eutectic Sn-Ag-Cu-base solders and eutectic Sn-Cu-base solders are going mainstream. As a result, the soldering temperature in surface mounting is usually in the range of 240 to 250°C. There is no Pb-free solder for a temperature hierarchy on the higher-temperature 10 side that can be used in combination with these eutectic Pb-free solders. As solders that provide the most suitable combinations, there are available Sn-5Sb solders (240-232°C). However, when temperature variations on a substrate in a reflow furnace, etc., 15 are considered, there is no highly reliable solder on the lower-temperature side that can perform bonding without melting the Sn-5Sb solders. On the other hand, although an Au-20Sn solder (melting point: 280°C) is known as a high-temperature solder, its use is limited 20 because it is a hard material and its cost is high. Especially, in bonding an Si chip to a material having a substantially different coefficient of expansion or in bonding a large-size Si chip, this solder is not used because it is hard and might break Si chips.

25 SUMMARY OF THE INVENTION

Against the above background, it is required that the necessity of use of Pb-free solders be met and

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that in mounting a module, after bonding by use of a higher-temperature side solder at a temperature of not more than 290°C, which does not exceed the heat resistance of parts (primary reflow), the terminal of the module be surface mounted (secondary reflow) to the external connection terminal of a printed circuit board, etc. by use of Sn-3Ag-0.5Cu solders (melting point: 217-221°C). For example, a module for a portable product in which chip parts and semiconductor chips are mounted (example: a high-frequency module) has been developed. In this module, the chip parts and semiconductor chips are bonded to the module substrate by use of high-temperature solders and cap encapsulation or resin encapsulation is required. These chip parts require bonding at a temperature of not more than 290°C maximum in terms of heat resistance. When the secondary reflow of this module is performed by use of an Sn-3Ag-0.5Cu solder, the soldering temperature reaches about 240°C. Therefore, because even an Sn-5Sb solder, which has the highest melting point of all Sn-base solders, has a melting point of 232°C and because the melting point decreases further when the plating of a chip electrode contains Pb, etc., it is impossible to avoid the remelting of the soldered portions of the chip parts in the module. Accordingly, a system or process that does not pose a problem even when a solder remelts is required.

It has been conventional practice to perform

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die bonding of chips to the module substrate at 290°C maximum by use of Pb-base solders and to perform the reflow of the chip parts. A soft silicon gel has been applied to wire-bonded chips, the top surface of the

5 module substrate has been protected with a cap made of Al, etc., and secondary reflow has been performed by use of eutectic Sn-Pb solders. For this reason, in secondary reflow, stresses are not applied even when part of the solder of module junctions melts and,

10 therefore, the chips do not move and there is no problem in high-frequency characteristics. However, it becomes necessary to perform secondary reflow by use of Pb-base solders and, at the same time, it has become necessary to develop a resin encapsulation type module

15 in order to reduce cost. In order to break through this, it is necessary to solve the following problems.

- 1) Reflow soldering in the air at a temperature of not more than 290°C must be possible (guaranteed heat resisting temperature of chip parts: 290°C).
- 20 2) Melting must not occur in secondary reflow (260°C maximum) or even if melting occurs, chips must not move (because high-frequency characteristics are affected if chips move).
- 3) Even when the solder within the module
- 25 remelts during secondary reflow, a short circuit due to the volume expansion of the solder of the chip parts must not occur.

Specifically, problems in the results of an

evaluation of an RF (radio frequency) module are stated below.

In an RF module, chip parts and a module substrate were bonded together by use of a conventional Pb-base solder (although this solder has a solidus line of 245°C, an Sn-Pb-base solder plating is applied to the connection terminals of the chip parts; for this reason, low-temperature Sn-Pb-base eutectics are formed and, therefore, remelting occurs) and the occurrence rate of short circuits due to the outflow of the solder after secondary mounting reflow was investigated in the module which was encapsulated so that it was covered by one operation with various types of insulating resins having varied moduli of elasticity.

FIG. 12(a) is an explanatory drawing of outflow, which show the principle of solder flow during the secondary mounting reflow of chip parts in a module. FIG. 12(b) is a perspective view of an example of solder flow of chip parts.

The mechanism of a short circuit due to a solder outflow is such that the melting and expanding pressure of a solder within a module causes the interfaces between chip parts and a resin or the interface between the resin and a module substrate to be exfoliated and the solder flows into the exfoliated interface(s), with the result that the terminals at both ends of a surface mounted part are connected to each other, causing a short circuit.

10 However, because low-elasticity resins in
practical use are silicone resins, during the process
of substrate dividing, part of the resins cannot be
completely divided and, in some cases, remain for
reasons of resin properties. Therefore, a process of
15 making cuts by a laser, etc. becomes necessary. On the
other hand, in the case of general epoxy resins,
mechanical dividing is possible although short circuits
occur because of hardness and these resins are
inappropriate. However, in terms of resin properties,
20 it is at present difficult to make the resins soft to
such an extent that short circuits do not occur at
180°C. If it is possible to perform resin
encapsulation that serves as mechanical protection and
can, at the same time, prevent a solder outflow,
25 covering with a case or cap is unnecessary and,
therefore, cost can be reduced.

An object of the present invention is to provide a completely new solder paste, a method of

the primary substrate is performed by the reflow of the solder paste containing the Cu balls and Sn solder balls and the bonding of the primary substrate to the secondary substrate is performed by the reflow of an
5 Sn-(2.0-3.5)Ag-(0.5-1.0)Cu solder.

For example, regarding temperature-hierarchical bonding, even when a part of solder on the higher-temperature side that has already been bonded melts, the solder can provide strength high enough to
10 withstand a process during later solder bonding if other portion does not melt.

The melting points of intermetallic compounds are high. Because portions bonded with intermetallic compounds can provide sufficient bonding strength even
15 at 300°C, intermetallic compounds can be used for temperature-hierarchical bonding on the higher-temperature side. Therefore, the present inventors performed bonding by use of a paste which is a mixture of Cu (or Ag, Au, Al or plastic) balls or these balls
20 whose surfaces are plated with Sn, etc. and Sn-base solder balls, both of them being mixed at a volume ratio of about 50% to about 50%. As the result, in portions where the Cu balls are in contact with each other or in close vicinity to each other, a reaction
25 with surrounding molten Sn occurs and a Cu_6Sn_5 intermetallic compound is formed because of diffusion between Cu and Sn, making it possible to ensure sufficient bonding strength between the Cu balls at

high temperatures. Because the melting point of this compound is high and sufficient strength is ensured at a soldering temperature of 250°C (only the Sn portion melts), no exfoliation of bonded portions occurs during secondary reflow performed for mounting onto a printed circuit board. Therefore, the soldered portions of a module are made of a composite material having two functions, that is, the first function of ensuring high-temperature strength during the secondary reflow by elastic bonding force brought about from the bonding of the high-melting point compound and the second function of ensuring service life by the flexibility of soft Sn during temperature cycles. Therefore, the soldered portions can be adequately used in the temperature-hierarchical bonding at the high temperatures.

Furthermore, also in the case of hard and high-rigidity solders having desirable melting points, such as an Au-20Sn solder, Au-(50-55)Sn solders (melting point: 309-370°C) and an Au-12Ge (melting point: 356°C), by using granular particles and dispersing and mixing soft and elastic rubber particles or by dispersing and mixing soft low-melting point solders of Sn, In, etc. among the above hard and high-rigidity solders, it is possible to ensure bonding strength even at temperatures of not less than the solidus temperatures of the above hard and high-rigidity solders and to relieve phenomena caused due to

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of Pb-base solders is 3.6% [Science and Engineering of
Metallic Materials; Masuo Kawamori, p. 14442]. In a
bonding structure of the invention, only Sn melts at
temperatures of about 240°C during secondary reflow
5 mounting. Therefore, in view of the fact that the
volume ratio of Cu balls to Sn balls is about 50%, the
volume expansion immediately after melting is 1.4%,
which is about 1/2.5 of that of Pb-base solders. On
the other hand, regarding the state of remelting, the
10 conventional solder instantaneously expands 3.6% when
it remelts. Therefore, in the case of a hard resin,
since the resin cannot be deformed, the pressure
increases, with the result that the molten solder flows
into the interfaces between the chip parts and the
15 resin. For this reason, it is necessary that the resin
be soft. On the other hand, with the solder of the
invention, as is apparent from a model of the section
of a chip shown in FIG. 1, Cu particles are bonded
together mainly via Cu_6Sn_5 compounds. Even when the Sn
20 in the gap among Cu particles melts, the Cu particles
do not move because they are bonded together.
Therefore, the pressure by the resin can be coped with
by the reaction force of the bonded Cu particles, with
the result that a pressure is not easily applied to the
25 molten Sn. Further, since the volume expansion of the
bonded portion is as low as 1/2.5 of that of the
conventional solder, it is expected that, because of
the synergistic effect of both of them, the possibility

charts of RF module mounting.

FIG. 9(a) to FIG. 9(d) are sectional views of a model of process sequence of an RF module.

FIG. 10 is a perspective view of the mounting
5 state of an RF module on a mounting substrate.

FIG. 11 is a perspective view of a method of resin printing in the assembling of an RF module.

FIG. 12(a) and FIG. 12(b) are a sectional view and a perspective view, respectively, of the principle of solder flow in a comparative example of RF module.

FIG. 13 shows a comparison of the phenomena of RF module between a comparative example and a example relating to the invention.

15 FIG. 14(a) to 14(c) are a plan view of a
high-output resin package and a sectional view of the
package.

FIG. 15 is a flow chart of the process of a high-output resin package.

20 FIG. 16(a) to FIG. 16(d) are sectional views
of a model of CSP junctions obtained by the bonding of
composite balls.

FIG. 17(a) to FIG. 17(c) are sectional views of a model of BGA/CSP in which Cu ball bumps are used.

25 FIG. 18(a) to FIG. 18(c) are sectional views
of a model of BGA/CSP in which Cu-coated bumps of
deformed structure are used.

FIG. 19 shows the relationship between the

Sn/Cu ratio and an appropriate range of bonding.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the invention are described below.

5 Embodiment 1

FIG. 1 shows the concept of a bonding structure relating to the invention. This figure also shows a condition before soldering and another condition after soldering. The upper portions of FIG. 10 1 shows an example of use of a paste in which Cu balls 1 with a particle size of about $30\mu\text{m}$ (or balls of Ag, Au, Cu-Sn alloys, etc., or those to which an Au plating, and Ni/Au plating, etc., are applied, or those to which an Sn plating, etc., are applied) and Sn 15 solder balls 2 (melting point: 232°C) with a particle size of about $30\mu\text{m}$ are appropriately dispersed in small quantities via a flux 4. When this paste is subjected to reflow at a temperature of not less than 250°C , the Sn solder balls 2 melt, molten Sn 3 spreads 20 so that it wets the Cu balls 1 and becomes present between the Cu balls 1 relatively uniformly. The Cu balls need not be spherical; that is, Cu balls having great surface irregularities, bar-like ones, and those containing dendrite crystals may be used. In this 25 case, the cubic ratio of Cu to Sn is different and it is only necessary that a Cu ball be in contact with an

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adjoining Cu ball. The superiority of the spherical shape lies in printability. After bonding, to ensure strength at high temperatures, it is necessary that the Cu balls be entangled with each other. On the other
5 hand, if the Cu balls are too much constrained by each other to move, there is no degree of freedom in soldering and deformability is insufficient, posing a problem. Regarding this respect, it seems ideal that the Cu balls in which dendritic crystals are linked by
10 contact with the result that elastic motion occurs. Thus, there is a method in which dendritic crystals of Cu are wrapped with Sn, etc. and are then sphered and the spheres are mixed. Incidentally, the particle size of the Cu and Sn balls is not limited to about $30\mu\text{m}$.

15 Because Cu_6Sn_5 compounds are formed in a short time by using a reflow temperature as high as possible, the aging process for the forming of the compound becomes unnecessary. When the forming of the Cu_6Sn_5 compound is insufficient, it is necessary to ensure the
20 strength of bonding between the Cu balls 1 by performing short aging in a temperature range of the heat resistance of the parts. Because the melting point of the Cu_6Sn_5 compound is as high as about 630°C and the mechanical properties of the Cu_6Sn_5 compound are
25 not poor, there is no problem in strength. If the aging is performed for a long time at a high temperature, Cu_3Sn compound comes to grow to the Cu side. It is thought that, regarding mechanical

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properties, Cu_3Sn is generally deemed to be hard and brittle. However, even when Cu_3Sn is formed within the solder around each of the Cu particles, there is no problem insofar as it has no effect on service life
5 measured in a temperature cycle test, etc. In an experiment in which Cu_3Sn was sufficiently formed at a high temperature in a short time, there was no problem in strength. It is thought that this is because there is a difference in the effect of Cu_3Sn on fracture
10 between such a case where Cu_3Sn is formed long along the bonding interface as to have so far been experienced and such another case where Cu_3Sn is formed around each of the particles as in this example. It is also thought that in the present case, a supplementary
15 effect of soft Sn present around the compound is also great.

Since, as disclosed above, the Cu balls 1 are bonded to each other via the compounds (Cu_6Sn_5), neither junctions (Cu_6Sn_5) nor Cu balls 1 melt, it becomes
20 possible to provide the bonding strength even when the module passes through a reflow furnace at about 240°C after bonding. In taking the reliability of bonding among the Cu balls 1 into account, it is preferred that the compounds (Cu_6Sn_5) be formed with a thickness of
25 about a few micrometers. Further, to ensure that the compounds are formed among the Cu balls 1, it is preferred the gap between the Cu balls be short so that they almost come into contact with each other. This is

Next, electronic parts such as LSI packages and parts having this bonding structure are mounted on a printed circuit board. In this mounting, temperature-hierarchical bonding becomes necessary.

- 5 For example, after printing of an Sn-3Ag-0.5Cu solder paste (melting point: 221-217°C) on connection terminals of a printed circuit board and mounting of electronic parts such as LSI packages and parts, reflow can be performed at 240°C in the air (this is possible
10 also in a nitrogen atmosphere). This Sn-(2.0-3.5)Ag-(0.5-1.0)Cu solder is treated as a standard solder that replaces conventional eutectic Sn-Pb solders. However, because this solder has a higher melting point than the eutectic Sn-Pb solders, it is required that a high-
15 temperature Pb-free solder suitable for this purpose be developed. As mentioned above, the strength at the high temperatures is ensured between Cu and Cu₆Sn₅ in already formed junctions and the strength of the junctions is high enough to withstand stresses caused
20 by the deformation of a printed circuit board during reflow, etc. Therefore, even when an Sn-(2.0-3.5) Ag-(0.5-1.0)Cu solder is used for the secondary reflow for soldering to a printed circuit board, this solder can realize temperature-hierarchical bonding because it has
25 such a function as to be a high-temperature solder. In this case, the flux to be used may be an RMA (rosin mild activated) type for non-cleaning application or an RA (rosin activated) type for cleaning application, and

sealing portion by means of a dispenser and a fine continuous pattern 12 are formed (FIG. 2(b)).

A model in which the section A-A' of the pattern is enlarged is shown on the right side. Cu balls 1 and Sn balls 2 are held by a flux 4. When bonding is performed by means of the pulse-current resistance heating body 15 while applying a pressure from above, the paste is made flat as shown in FIG. 2(c). Section B-B' which is made flat is enlarged on the right side. In this case, when Cu balls of 30 μm are used, the solder bonding portion between a junction substrate 6 and a cap 9 provides a gap corresponding to 1 to 1.5 Cu ball (about 50 μm). Because bonding under pressure by means of the pulse heater was performed at 350°C for 5 seconds, the contact portion between the Cu ball 1 and the terminal of the junction substrate 6 and the contact portion between the Cu ball and the cap 9 readily form Cu_6Sn_5 or Ni_3Sn_4 compounds in a short time insofar as a thick Cu-base or Ni-base plating layer is formed on the cap surface. In this case, therefore, the aging process is generally unnecessary. When a narrow paste application width is intentionally adopted, for example, when the paste is applied under pressure to a section of 250 μm in width x 120 μm in height, the thickness of the section becomes equivalent to the thickness of 1 to 1.5 particle after pressure application and hence it comes to spread to a width of about 750 μm .

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Eutectic Sn-0.75Cu solder balls are supplied beforehand to this encapsulated package as external junction terminals 11, and on the printed circuit board, the solder paste is positioned and provided, as
5 with other parts, by printing, and the surface mounting is performed by reflow. As a reflow solder, any one of an Sn-3Ag solder (melting point: 221°C, reflow temperature: 250°C), an Sn-0.75Cu solder (melting point: 228°C, reflow temperature: 250°C), Sn-3Ag-0.5Cu
10 solders (melting point: 221-217°C, reflow temperature: 240°C), and etc. may be used. Because as is apparent from the results so far obtained, sufficient strength is ensured between Cu and Cu_6Sn_5 by the eutectic Sn-Pb solder, encapsulated portions, etc., are not exfoliated
15 during reflow. Incidentally, when a lap-type joint portion obtained by bonding pieces of Cu foil together by use of this solder paste was subjected to a shearing tensile test (tensile rate: 50 mm/min) at 270°C, the value of about 0.3 kgf/mm² were obtained. This reveals
20 that a sufficient strength at high temperatures is ensured in the junction.

In the case of a module whose cap portion is made of Al plated with Ni-Au or made of Fe-Ni plated therewith, the growth rate of an Ni-Sn alloy layer at
25 a temperature of not less than 175°C is higher than that of a Cu-Sn alloy layer insofar as the Ni-containing layer is formed with a film thickness of about 3 μm (for example, D. Olsen et al.; Reliability

Physics, 13th Annual Proc., pp 80-86, 1975) and, therefore, an Ni_3Sn_4 alloy layer is also sufficiently formed by high-temperature aging. However, as regards the properties of the alloy layer, Cu_6Sn_5 is superior.

Thus, it is not preferred to make the Ni_3Sn_4 alloy layer grow to have a thicker thickness. In this case, because the high-temperature aging cannot be made to be a long period of time, there occurs no problem of embrittlement caused due to excessive growth. From data on an Sn-40Pb solder which has a lower growth rate of an alloy layer than Sn and which has been used in actual operations, it is possible to predict an outline of the growth rate of Sn. The growth rate of occurring by Ni and Sn-40Pb is not more than $1\mu\text{m}$ even at 280°C in 10 hours (according to some data, the growth rate is $1\mu\text{m}$ at 170°C in 8 hours). Thus, no problem of the embrittlement occurs insofar as the high temperature aging is short in the period of time. As regards the growth rate of the alloy layer (Ni_3Sn_4) occurring by Sn and the Ni plating, it is known that the growth rate thereof differs greatly in dependence on the types of plating such as electroplating and chemical plating etc. Because it is necessary to keep the high bonding strength, a high growth rate of the alloy layer is desired in the embodiment. On the other hand, there is such a data as the growth rate of Cu_6Sn_5 occurring by Cu and the Sn-40Pb solder is $1\mu\text{m}$ at 170°C in 6 hours (which corresponds to a growth rate of $1\mu\text{m}$ per one hour

at 230°C in the case of the Sn-0.75Cu eutectic solder balls used in the embodiment on the assumption that the solder balls are simply in a solid state). In a bonding experiment at 350°C for 5 seconds, the inventors were able to observe portions where Cu_6Sn_5 of 5 μm maximum in thickness were formed between Cu particles. From this fact, it is deemed that no aging process is generally necessary when the soldering is performed at the high temperature.

10 In this paste method, it is also one of the
most important problems to reduce the occurrence of
voids as little as possible. For this reducing, it is
important to improve the wettability of the solder for
the Cu particles and to improve the fluidity of the
15 solder. For achieving this, the Sn plating on the Cu
balls, Sn-Cu solder plating thereon, Sn-Bi solder
plating thereon and Sn-Ag solder plating thereon, the
adoption of eutectic Sn-0.7Cu solder balls, Bi addition
to solder balls, and etc., are effective means.

20 Further, the solder balls are not limited to Sn solder balls, and solder balls may be used in which any one or more of eutectic Sn-Cu-base solder balls, eutectic Sn-Ag-base solder balls, eutectic Sn-Ag-Cu-base solder balls, and solder balls obtained by adding
25 at least one element selected from In, Zn, Bi, etc. to any one of these solder balls may be used. Also, in these cases, because Sn is the main element of the composition, the desired compound can be formed. Also,

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two or more kinds of balls may be mixed. Because in these balls the melting point of these balls is lower than Sn, the growth rate of the alloy layer at high temperatures generally tends to become high.

5 Embodiment 3

The paste relating to the invention can also be used in the die bonding 7 shown in FIG. 2(a). After bonding by use of the paste relating to the invention, cleaning and wire bonding are performed. In prior arts, the die bonding is performed by use of an Au-20Sn solder, however, it has been limited to small chips in view of reliability. Also, in the case of Pb-base solders, a Pb-10Sn solder, etc., have been used. The bonding relating to the invention can be used even in chips having a somewhat larger area. The larger the thickness of a bonding portion, the longer the service life and the higher the reliability become. In the invention, it is possible to make this thickness larger by using high melting point balls each having a larger size. In a case of making this thickness small, this is performed by making the size of particles (, that is, balls) small. In some bonding methods, it is also possible to use a thin bonding portion by reducing the particle size. Even Cu particle sizes of 5-10 μm may be also used, and particles of further smaller size may be mixed therewith. The compounds occurring between an Si chip (Cr-Cu-Au, Ni plating, etc., is provided as the

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metallized layer of the back side thereof) and Cu balls and between Cu balls and the connection terminal on the substrate include Sn-Cu compounds and Sn-Ni compounds. Since the growth rate of the alloy layer is small, no
5 problem of embrittlement occurs.

Embodiment 4

The junction provided by a high-temperature solder needs to withstand only during reflow which is performed in a succeeding step, and the stress applied
10 to this junction during the reflow is thought to be small. Therefore, instead of using the metal balls, one side or both sides of each of connection terminals are roughened so that projections of Cu, Ni, etc. may be formed, whereby an alloy layer is formed surely at
15 the contact portions of the projections and other portions are bonded with a solder. This provides the same effect as with the balls. The solder is applied to one of the terminals by means of a dispenser, the solder being then made to melt while the projections
20 are made from the above to be forced to intrude into each other by means of a resistance heating body of pulsed electric current, whereby the die bonding is performed at a high temperature. As a result, because of the anchor effect of the projections and the
25 formation of the compounds in the contact portions, the contact portions can obtain strength high enough to withstand the stress occurring during the reflow. FIG.

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3(a) shows a model of the section of a junction in which the surface of a Cu pad 18 of a substrate 19 is roughened by etching and a paste of an Sn-base solder 2 is applied to the roughened surface. In this case, 5 fine Cu particles, etc., may be added to the Sn-base solder. The back side of a terminal portion 75 of a part may be flat. In this case, however, it was plated with Cu or Ni, etc. and the surface thereof was roughened by etching 20. FIG. 3(b) shows a state of 10 the bonding performed by heating under pressure. The compounds are formed in the contact portions by the reflow performed at a somewhat high temperature, so that the contact portion becomes strong in strength. Therefore, in the succeeding reflow step in which the 15 external connection terminals are bonded to the terminals of the substrate, this portion is not exfoliated.

Embodiment 5

In bonding by use of Au-Sn alloys in which 20 the amount of diffused elements is increased by aging and regarding which resultant compounds change in about three stages from a low-temperature to a high-melting point side, various compounds are formed at relatively low temperatures within a range of a small temperature 25 variation. A well-known composition of the Au-Sn alloy is Au-20Sn (melting point: 280°C, eutectic type). The composition range of Sn in which the eutectic

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temperature of 280°C is maintained is from about 10 to 37 mass% Sn. There occurs a tendency to become brittle when the Sn content thereof increases. It is deemed that a composition range which may be realized in an alloy containing Au of a low content is 55 to 70% Sn, and in this composition a 252°C-phase comes to be present (Hansen; Constitution of Binary Alloys, McGRAW-HILL, 1958). Since the possibility that the temperature of a portion bonded in the preceding step (primary reflow) reaches 252°C after the bonding in a succeeding step (secondary reflow) is thought to be low, it is thought that even in this composition range, the purpose of temperature-hierarchical bonding can be achieved. As regards the compositions, AuSn₂ and AuSn₄ are formed, which can be applied to the die bonding or to the encapsulation portion of the cap. For further extra safety, an Au-Sn alloy containing Sn of 50 to 55 mass% may be adopted, in which alloy the solidus line and the liquidus line thereof become 309°C and maximum 370°C, respectively, so that it becomes possible to prevent the 252°C-phase from occurring. FIG. 4 shows a model of a section in which the back side of an Si chip is plated beforehand with Ni(2 μm)-Au (0.1 μm) , for example, taps on a lead frame 19 being plated with Ni(2 μm)-22-Sn(2-3 μm) 23. In the die bonding performed in a nitrogen atmosphere while heating under pressure and in the aging additionally applied as occasion required, a part of Sn is consumed to form the Ni-Sn alloy layer

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(, that is, the Ni-Sn compound layer) and the remainder of Sn forms an Au-Sn alloy phase. In a case where the Sn content is too high, a low eutectic point (217°C) of Sn and AuSn_4 is formed. Therefore, it is necessary to
5 control the Sn content so that this eutectic point may be not formed. Alternatively, a paste in which fine metal particles and Sn, etc., are mixed may be coated thereon. Because the die bonding by use of Au-Sn solders is performed at a high temperature of 350--
10 380°C , it is possible to form a compound in which the Sn content is lower than that of the AuSn_2 , by controlling the film thickness, temperature and a period of time, whereby the melting point thereof can be made to be not less than 252°C . Thus, it is thought
15 that no problem occurs in the succeeding reflow step.

As mentioned above, by causing the solder to melt at 300°C levels, which are considerably higher than the melting point of Sn, the diffusion of the elements was activated and the compound were formed,
20 whereby the strength required at the high temperature was able to be ensured and the high-reliability bonding thereof on the higher-temperature side in the temperature-hierarchical bonding was able to be realized.

25 As regards the metal balls described above, there may be used any one of the balls of single-element metal (for example, Cu, Ag, Au, Al and Ni), the balls of alloy (for example, Cu alloy, Cu-Sn alloy and

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this provides a great cost merit. Trace amounts of Ag, Zn, Cu, Ni, etc. may be added to Sn so that Sn reacts readily with Al. The Al surface can be wetted either completely or in spots. When stress is applied in the
5 latter case of spots-like wetting, because restraining from deforming becomes small insofar as a bonding strength is ensured, deformability is good and the unwetted portions absorb energy as friction loss. Therefore, a material excellent in deformability is
10 obtained. It is also possible to plate an Al wire with Sn, Ni-Sn, Ag, etc. and cut it in particle forms. Al particles can be produced in large amounts at low cost by the atomization process, etc. in a nitrogen atmosphere. It is difficult to produce Al particles
15 without surface oxidation. However, even when the surface is once oxidized, oxide films can be removed by the metallizing treatment.

Embodiment 7

Next, Au balls are described. In the case of
20 the Au balls, Sn readily wets them and, therefore, metallizing is unnecessary insofar as bonding performed in a short time is concerned. However, in a case where the soldering time is long, Sn diffuses remarkably and there occurs such a fear as brittle Au-Sn compounds are
25 caused. For this reason, in order to ensure a soft structure, In (, that is, indium)plating in which the degree of diffusion to Au is low, etc. is effective,

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and Ni, Ni-Au, and etc. used as a barrier are also effective. Forming a barrier layer that is made to be as thin as possible makes Au balls readily deformable. Alternatively, other metallized structures may also be adopted insofar as they can suppress the growth of an alloy layer with Au. When the bonding is performed in a short time in the die bonding, an alloy layer formed at grain boundaries is thin in thickness, so that the effect brought about by the flexibility of Au can be greatly expected even in a case where no barrier is provided. The combination of the Au balls and In solder balls is also possible.

Embodiment 8

Next, Ag balls are described. The case of the Ag balls is also similar to that of the Cu balls. Since the mechanical properties of Ag_3Sn compounds such as hardness and etc. are not poor, so that it is also possible to perform the bonding of the Ag particles together through the compounds by a usual process. It is also possible that Ag balls are mixed in Cu, etc.

Embodiment 9

Next, there is described a case where a metal material are used as metal balls. As representative alloy-base materials, Zn-Al-base and Au-Sn-base materials are available. The melting point of a Zn-Al-base solder are mainly in the range from 330°C to

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370°C, which are suitable for performing the hierarchical bonding with a Sn-Ag-Cu-base solder, a Sn-Ag-base solder and a Sn-Cu-base solder. As representative examples of the Zn-Al-base solder, there are available a Zn-Al-Mg-base solder, a Zn-Al-Mg-Ga-base solder, a Zn-Al-Ge-base solder, a Zn-Al-Mg-Ge-base solder, and any one of these solders that contains at least one kind selected from Sn, In, Ag, Cu, Au, Ni, and etc. In the case of the Zn-Al-base solder, the oxidation thereof occurs intensively and the solder rigidity thereof is high. For these reasons, it is pointed out that cracks may occur in Si chips when Si is bonded (Shimizu et al.: "Zn-Al-Mg-Ga Alloys for Pb-Free Solders for Die Attachment," Mate 99, 1992-2).

Thus, these problems must be solved when the Zn-Al-base solder is used as metal balls.

Accordingly, in order to solve these problems, that is, in order to lower the rigidity of the solders, heat-resistant plastic balls plated with Ni/solder, or Ni/Cu/solder, or Ni/Ag/solder or Au were uniformly dispersed in the Zn-Al-base balls to thereby lower Young's modulus. It is preferred that each of these dispersed particles be smaller in size than that of the Zn-Al-base balls and be uniformly dispersed in the Zn-Al-base balls. At the time of the deformation, the soft plastic balls with elasticity having a size of about 1 μm deform, so that there is brought about a great effect on the relieving of thermal impact and

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mechanical impact. When a rubber is dispersed in the Zn-Al-base solder balls, the Young's modulus decreases. Since the plastic balls are almost uniformly located among the Zn-Al-base solder balls, this dispersion is
5 not greatly varied during the melting performed in a short time. Further, by using plastic balls whose thermal decomposition temperature is about 400°C, the organic substances thereof can be prevented from being decomposed in the solder during the bonding performed
10 through the resistance heating body.

The Zn-Al is apt to be readily oxidized. Thus, in taking the storage thereof and etc. into consideration, it is preferred that the surface thereof be plated with Sn formed by replacing Cu. The Sn and
15 Cu dissolve during the bonding in the Zn-Al solder insofar as a low amount of Sn and Cu is concerned. Because of the presence of Sn on the surface, it become easy to perform, for example, the bonding onto an Ni/Au plating formed on a Cu stem. At such a high
20 temperature as to be not less than 200°C, the growth rate of an Ni-Sn alloy layer (Ni_3Sn_4) is larger than that of Cu_6Sn_5 , so that there occurs no phenomenon that the bonding were impossible due to insufficient formation of the compounds.

25 Further, by making the Sn balls of 5-50% mixed therein in addition to the plastic balls, Sn layers come to be located among the Zn-Al-base solders. In this case, a part of the Zn-Al balls are bonded

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directly to each other, however, in the other portions, relatively soft Sn-Zn phase of a low melting point and remaining Sn and etc. come to be present, so that any deformation can be absorbed by the Sn, the Sn-Zn phase
5 and the rubber of the plastic balls. In particular, because of a combined action of the plastic balls and the Sn layers, further relieving of the rigidity can be expected. Even in this case, the solidus line temperatures of the Zn-Al-base solder is ensured to be
10 not less than 280°C, so that there is no problem regarding the strength required at high temperatures.

By plating the Zn-Al-base solder balls with Sn so that Sn phase which remains without being dissolved in the balls may be present, the Sn phase
15 acts to absorb the deformation, so that the rigidity of the Zn-Al solder balls can be relieved. In order to further relieving the rigidity, the Zn-Al-base solder balls may be used while mixing therein plastic balls having a size of about 1 μ m which are coated by
20 metallizing and soldering, so that the impact resistance thereof is improved and the Young's modulus thereof decreases. Alternatively, by using a paste in which the balls of Sn, In, etc. and the rubber of the Sn-plated plastic balls are dispersed in the Zn-Al-base
25 (for example, Zn-Al-Mg, Zn-Al-Ge, Zn-Al-Mg-Ge and Zn-Al-Mg-Ga) solder balls, it is possible to similarly improve temperature cycle resistance and impact resistance, whereby the high reliability thereof can be

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ensured. When only the Zn-Al-base solders are used, the balls are hard (about Hv 120-160) and the rigidity is large, so that there occurs such a fear as a Si chip of a large size is broken. For removing this fear, the
5 layers of soft, low-melting point Sn and In are made to be present around the balls, and the rubber is dispersed among the balls, whereby the deformability is ensured and the rigidity decreases.

Embodiment 10

10 FIG. 5(a) to FIG. 5(c) show an example in which a relatively small output module and etc. used for signal-processing in portable cellular phones, which module has such a large square shape as one side thereof is larger than 15 mm in length, are mounted to
15 a printed circuit board by a flat pack type package structure in which a difference in thermal expansion coefficient between the module and the substrate is relieved by leads. In this type of structure, it is usual to adopt the system that the rear face of each of
20 circuit elements is die-bonded to a junction substrate excellent in thermal conductivity and they are connected to the terminal of the junction substrate by wire bonding. Regarding this system, there are many examples in which a MCM (multi chip module) design is
25 adopted in which there are located several chips and chip parts such as of resistors and capacitors arranged around each of the chips. A conventional HIC (hybrid

In a case where there is used a thick film substrate such as an AlN substrate, a glass ceramic substrate or an Al_2O_3 substrate instead of using the Si substrate, the mounting of the resistors, capacitors, etc. as the parts of the chips becomes basic. Further, there is available a forming method in which laser trimming is performed while using a thick-film paste. In the case of resistors and capacitors formed by the thick-film paste, it is possible to adopt the same mounting system as in the above Si substrate.

FIG. 5(b) shows another system comprising the steps of mounting the chips 8 of Si or GaAs, with its face up, on an Al_2O_3 substrate 19 excellent in thermal conductivity and in mechanical properties, performing the bonding thereof under pressure by means of a pulse resistance heating body, performing the reflow bonding of chip parts, performing the cleaning thereof, and performing the wire bonding. In this case, resin encapsulation is a general practice similarly to the case of Fig. 5(a). The resin used therein is, similarly to the case of Fig. 5(a), an epoxy resin of low thermal expansion coefficient in which a quartz filler and rubber such as a silicone rubber are dispersed and which can reduce thermal impacts, or a silicone resin, or a resin in which the two of the resins are mixed in some states or forms. In this system, a large substrate of an undivided state is used insofar as the mounting of the chips and the chip parts

In the case of the bonding of Al fins, if a non-cleaning type is possible, there is available a system comprising the steps of supplying the paste in a shape surrounding the fins by means of a dispenser or printing, and performing the bonding under pressure by means of the resistance heating body or a laser or a light beam etc. or bonding by one operation simultaneously with the chip parts by the reflow. In the case of Al materials, plating with Ni, etc. is performed as metallizing. In the case of the fin

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bonding, in order to realize the non-cleaning type, Al is worked to be in a foil shape and the foil thus obtained is bonded under pressure in an N₂ atmosphere by means of the resistance heating body.

5 FIG. 5 (c) shows a part of a module structure in which electronic parts are mounted on a metal-core substrate having a metal 39 therein and are encapsulated with an Al fin 31. A chip 13 may have a face-down structure and may be directly bonded to the
10 metal 39 of the metal core by installing dummy terminals 45 for heat dissipation. The bonding is performed by LGA (lead grid array) system, the pads of a chip-side being made of Ni/Au or Ag-Pt/Ni/Au, the pads of a substrate-side being made of Cu/Ni/Au, and
15 these are bonded to each other by use of the paste relating to the invention. In a case of using a polyimide substrate that has a low thermal expansion and a heat resisting property or using a built-up substrate having similarly thereto a heat resisting
20 property, the module mounting with the temperature hierarchy can be performed in which the semiconductor devices 13 are directly mounted by use of a paste 36 relating to the invention. In the case of a chip of high heat generation, it is also possible that the heat
25 is conducted to the metal 39 through the thermal vias. Since in each of the thermal vias Cu particles contact with each other are present, the heat is instantaneously conducted to the metal, that is, this

electrically-conductive paste 54. The circuit element is connected to each of leads 29 by wire bonding while using a gold wire 8, etc. and is molded with a resin 5. After that, the leads are plated with Sn-based solder 5 corresponded to the Pb-free bonding design.

Conventionally, a eutectic Sn-37Pb solder with a melting point of 183°C was able to be used for the mounting on a printed circuit board and, therefore, it was possible to perform the reflow bonding at 220°C maximum. However, in the case of the Pb-free bonding, since the reflow bonding is performed by use of the Sn-3Ag-0.5Cu solder (melting point: 217-221°C), the reflow temperature becomes about 240°C, that is, the maximum temperature becomes higher by about 20°C than that of the conventional technique. Thus, insofar as a conventionally used heat-resistant, electrically-conductive paste used for the bonding between the Si chip 25 and the tab 53 of 42-Alloy is concerned, the bonding strength at the high temperature decreases, and there occurs such a fear as the reliability thereof is affect. Therefore, by using the paste relating to the invention in place of the electrically-conductive paste, it becomes possible to perform the Pb-free bonding at about 290°C with respect to the die bonding.

This application to a plastic package can be applied in all plastic package structures in which an Si chip and a tab are bonded together. As for the shape of the leads, structurally there are the gull wing type, the

printed circuit board, etc., and in this case the temperature-hierarchical bonding is required.

FIG. 7 (c) shows an example in which, besides this FR module, a semiconductor device of BGA type and
5 a chip part 17 are mounted on a printed circuit board 49. In the semiconductor device, a semiconductor chip 25 is bonded, in a face-up state, to a junction substrate 14 by use of the solder paste relating to the invention, the terminals of the semiconductor chip 25
10 and the terminals of the junction substrate 14 being bonded together by wire bonding, and the areas around the bonding portions are resin-encapsulated. For example, the semiconductor chip 25 is die-bonded to the junction substrate 14 through the resistance heating
15 body by melting the solder paste at 290°C for 5 seconds. Further, on the rear face of the junction substrate 14 is formed solder ball terminals 30. For example, a Sn-3Ag-0.5Cu solder is used in the solder ball terminals 30. Moreover, also to the rear face of
20 the substrate 49 is solder-bonded a semiconductor device (in this example, TSOP-LSI), which is an example of so-called double-sided mounting.

As a method of the double-sided mounting, for example, a Sn-3Ag-0.5Cu solder paste is first printed
25 in pad portions 18 on the substrate 49. Then, to perform solder bonding from the side of the mounting face of a semiconductor device such as TSOP-LSI50, TSOP-LSI50 is located and the reflow bonding thereof is

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because of their high melting points. Further, because the die bonding temperature is higher than the secondary reflow temperature, Sn wets and spreads out sufficiently to thereby becomes the compound. As the
 5 result thereof, during the secondary reflow, the compound layers come to provide a sufficient strength at the high temperatures, so that the Si does not move even in the resin-encapsulated structure. Further, even in a case where the low-melting point Sn remelts,
 10 it does not flow out because it has already been subjected to the heat history of the higher temperatures. For these reasons, the Si chip remains stationary during the secondary reflow, so that the module characteristics are not affected by the re-
 15 melting of Sn.

Next, there are below described influences caused by the resin while comparing the case of the paste relating to the invention with that of conventional the Pb-base solder (which makes it
 20 possible to perform the reflow at 290°C.

In FIG. 12(a) and FIG. 12(b) there is shown a model of a phenomenon of a short circuit caused in a chip part 17 by the flowing-out 71 of a conventional Pb base solder (having a solidus line temperature of
 25 245°C) in a case where the secondary reflow (220°C) for performing the bonding to a printed circuit board is performed (, which is similar to the mounting state of Fig. 11 and the composition of the solder 30 is a Sn-Pb

multichip modules, and etc.

Embodiment 14

Next, there is described an example of application of the invention to the resin package of a high-output chip such as a motor-driver IC. FIG. 14(a) is a plan view of the high-output resin package in which a lead frame 51 and a thermal-diffusion plate 52 are bonded together and caulked. FIG. 14(b) is a sectional view of the package. FIG. 14(c) is a partially enlarged view of a circle portion in FIG. 14(b). In this example, a semiconductor chip 25 is bonded to a thermal-diffusion plate (heat sink) 52 by use of the solder paste relating to the invention. The lead 51 and the terminals of the semiconductor chip 25 are bonded together by wire bonding and are resin encapsulated. The lead is made of a Cu-base material.

FIG. 15 is a flow chart of the steps of the high-output resin package. First, onto the lead frame 51 and the thermal-diffusion plate 52 both joined by
20 caulking is die-bonded a semiconductor chip 25 by supplying a solder paste 3. The semiconductor chip 25 bonded by the die bonding is further wire bonded, as shown in the figure, by means of the lead 51, a gold wire 8 and etc. After that, the resin encapsulation is
25 performed and the Sn-base solder plating is performed after the dam cutting. Then, lead-cutting and lead-forming are performed, the cutting of the thermal-

For a large chip, it is preferred that, in the case of an especially hard Zn-Al-base solder, high reliability be ensured by adding rubber and a low-expansion filler.

15 Embodiment 15

FIG. 16(a) to FIG. 16(d) show, regarding examples of BGA and CSP, a package of a chip 25 and a junction substrate 14 which package is obtained by the temperature-hierarchical bonding of the Pb-free solder 20 by use of Cu balls 80 capable of keeping a strength even at 270°C. Conventionally, the temperature-hierarchical bonding was performed by use of high melting Pb-(5-10)Sn solders for bonding a chip and a ceramic junction substrate together. However, when Pb-free solders are to be used, there is no means that replace the conventional one. Therefore, there is provided such a structure as, by use of a Sn base

solder and a compound occurring thereby, a bonded portion is not melted at the time of the reflow to thereby maintain a bonding strength even when the portion of the solder is melted. FIG. 16(a) shows a sectional model of BGA/CSP, in which an organic substrate such as a built-up substrate was used as the junction substrate although a built-up substrate, metal-core substrate, ceramic substrate and etc., can be considered. As regards the shape of a bump, there are a ball bump (FIG. 16(b)), a wire bond bump (FIG. 16(c)) and a Cu-plated bump of a readily deformable structure (FIG. 16(d)). The external connection terminals are Cu pads or Sn-Ag-Cu-base solder portions fed through balls or paste on Ni/Au-plating portions

In the case shown in FIG. 16(a), it becomes possible to obtain bonding capable of withstanding the reflow by the steps of: feeding Sn onto a thin-film pads 82 on the side of the Si chip 25 by means of vapor deposition, plating, a paste, or the composite paste including metal balls and solder balls; thermally pressure-bonding thereto metal balls 80 such as balls of Cu, Ag, Au, etc. or Au-plated Al balls, or metallized organic resin balls to thereby form an intermetallic compound 84 with Sn at contact portions 84 in contact with the thin-film pad material (Cu, Ni, Ag, etc.) or in the vicinity of this contact portion. Next, the ball pads formed on the above chip is

positioned on the pads of a junction substrate (an Al_2O_3 , AlN , an organic, a built-up substrate or a metal-core substrate), to which pads a paste comprising metal balls, a solder (Sn , Sn-Ag , Sn-Ag-Cu , Sn-Cu , etc. or those containing at least one of In , Bi and Zn) and balls is supplied beforehand, and is thermally pressure-bonded, whereby similarly a compound 84 of the pads 83 of the junction-substrate and Sn is formed to thereby make it possible to provide a structure capable of withstanding 280°C . Even when the bump height varies, the variation is compensated for by the composite paste. Thus, it becomes possible to obtain BGA or CSP or high reliability in which stress burden to each of the solder bumps and to the Si chip pads is small with the result that the service life of the bumps is increased and in which, for the mechanical protection against the impact of fall and etc., the filling is formed with a solvent-free resin 81 superior in fluidity having Young's modulus in the range of 50 to 15000 Mpa and a coefficient of thermal expansion of 10 to $60 \times 10^{-6}/^\circ\text{C}$.

The processes of FIG. 16(b) to FIG. 16(d) are described below.

FIG. 17(a) to FIG. 17(c) show a bonding
25 process for bonding the Si chip 25 and the junction
substrate 14 together, by the system of the Cu ball 80
shown in FIG. 16(b). Although the electrode terminals
82 on the chip 20 are made of Ti/Pt/Au in this case,

the material is not limited to the Ti/Pt/Au. In the stage of wafer process, an Sn plating, an Sn-Ag-Cu-base solder or a composite paste 85 containing metal balls and solder balls is fed to the thin-film pads 82 formed on each chip. Au is provided mainly for the prevention of surface oxidation and is as thin as not more than 0.1 μm . Therefore, Au dissolves in the solder in a solid solution state after melting. As regards the Pt-Sn compound layers, there are present various compounds such as Pt_3Sn and PtSn_2 . When the diameter of the ball 80 is large, it is desirable to adopt a printing method capable of supplying a thick solder 85 for fixing the balls. Alternatively, balls which are solder plated beforehand may be used.

FIG. 17(a) shows a state in which a 150- μ m metal ball (Cu ball) 80 is positioned and fixed by a metal-mask guide after the application of a flux 4 onto the terminal plated with Sn 23. To ensure that all balls on the wafer or chip come into positive contact with the central part of the thin-film pads 82, melting under pressure is performed at 290°C for 5 seconds by means of a flat pulse-current resistance heating body, etc. Due to size variations of Cu balls in the chip, some balls do not come into contact with the pad portions, however, in a case where these balls are close to the pad portions, the possibility of the forming of an alloy layer becomes high, although this depends on the plastic deformation of Cu at high

The section of the electrode portion after melting is shown in FIG. 17(b). The Cu ball comes into contact with the terminal, and a contact portion 84 is bonded by compounds of Pt-Sn and Cu-Sn. Even in a case where the contact portions are not bonded completely by the compounds, there is such a case as the alloy layer grows because of heating, pressurization, etc. in succeeding steps with the result that the joining thereof is achieved. Although Sn fillets are formed in the surrounding area, Sn often does not always wet to spread on the whole Cu. After the bonding of the ball, cleaning is performed for each wafer or chip (in the case of a wafer, the wafer is cut for each chip), the back side of the chip being then attracted by means of the pulse-current resistance heating body, the ball terminal being positioned and fixed to a composite paste 36 formed on the electrode terminal 83 of a built-up junction substrate 14, and melting under pressure is performed at 290°C for 5 seconds while spraying a

nitrogen gas. A flux may be used when no resin-filling is performed in the succeeding step.

FIG. 17(c) shows a section after the melting under pressure. From the electrode terminal 82 on the chip side to the electrode terminal 83 on the junction substrate side, all of the high-melting metals and the intermetallic compounds etc. 41 are connected to each other in succession, so that no exfoliation occurs even in the succeeding reflow step. Due to height variations of the ball bumps, some bumps do not come into contact with the pads on the junction substrate. However, because these ball bumps are connected by the intermetallic compounds 84, there occurs no problem even during the reflow.

FIG. 16(c) shows an example in which a wire bonding terminal (Cr/Ni/Au, etc.) 48 on the Si chip side and a wire bumping terminal 86, etc. of Cu, Ag or Au etc. are bonded together by thermal pressure bonding (in some cases, an ultrasonic wave may be applied thereto). The feature of the wire bumping terminal are its shape deformed by capillaries and its torn neck portion. Although height variations in the torn neck portion are large, in some of them the irregular heights are made to be flat during the lpressurization and, since it is bonded by the mixture paste, there occurs no problem. As the material for the wire bumping terminal, there are materials of Au, Ag, Cu and Al which wet well with Sn and are soft. In the case of

formed by use of the photoresist 89 and plating and thereafter the photoresist is removed so that a Cu bump may be formed. FIG. 18(b) shows the section of a bonding portion formed between the Cu bump 91 and the Cu terminal through the intermetallic compound 84 of Cu_6Sn_5 by the steps of coating the junction substrate 14 with a composite paste of Cu and Sn, positioning the Cu bump 91 of the chip, and pressurizing and heating it (at 290°C for 5 seconds) in a nitrogen atmosphere without using a flux.

Embodiment 16

Next, to examine an appropriate range of the ratio of the metal balls included in the solder paste (Cu was selected as a representative component) to solder balls (Sn was selected as a representative component), the weight ratio of Sn to Cu (Sn/Cu) was varied. The result of the examination is shown in FIG. 19. As regards a method of evaluation, the section of a bonding portion after the reflow was observed and appropriate amounts of the mixed components were examined from the states of the contact and/or the approaching of Cu particles, etc. The flux used here was a usual non-cleaning type. As regards the particle sizes of Cu and Sn, relatively large particles of 20 to 40 μm were used. As the result, it is found that the Sn/Cu ratio range is preferably in the range of 0.6 to 1.4 and more preferably 0.8 to 1.0. Unless the

In order to reduce the rigidity of the composite solder, it is effective to disperse among the metal and solder balls the soft, metallized plastic balls. In particular, in the case of a hard metal, this is effective in improving the reliability because the soft plastic balls act to reduce the deformation and thermal impact. Similarly, by dispersing

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